

SECTION 34 21 11

DC CIRCUIT BREAKER MULTI-FUNCTION PROTECTION RELAY

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. DC feeder breaker automatic reclosing
- B. Short circuit protection
- C. Contact rail potential indication
- D. Relay data logging
- E. Remote communication
- F. Relay equipments
- G. High voltage input signal collection equipment

1.02 MEASUREMENT AND PAYMENT

- A. DC circuit breaker multi-function protection relay, as specified herein, will not be measured separately for payment but will be paid for as part of the Contract lump-sum price for the related item of work in the Bid Schedule of the Bid Form.

1.03 REFERENCES

- A. Institute of Electrical and Electronics Engineers (IEEE)
 - 1. IEEE 37.20.1 IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear, 1993.
 - 2. IEEE 37.90 IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus, 1994.
 - 3. IEEE 37.90.1 IEEE Standard for Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems, 1994.
- B. American National Standards Institute (ANSI)
 - 1. ANSI / EIA-232-F Interface Between Data Terminal Equipment and Data Circuit –Terminating Equipment Employing Serial Binary Data Interchange, 1997.
- C. National Electrical Manufacturers Association (NEMA)
 - 1. NEMA 250 Enclosures for Electrical Equipment (1000V Maximum), 1991.

2. NEMA WC70 / ICEA S-95-658 Standard for Non-Shielded Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy, 1999.

D. National Fire Protection Association (NFPA)

1. NFPA 70 National Electric Code, 2000.

1.04 DESCRIPTION

- A. DC MPR equipment shall provide dc circuit breaker controls and protection for traction power substations (TPSS) and gap breaker stations (GBS). In traction power substations (TPSS), the dc feeder breakers connect the dc main bus to contact rail sections. In gap breaker stations (GBS), the dc feeder breakers connect adjoining contact rail sections.
- B. Standard BART DC MPR functions and parameters described herein are those used in the core BART system, and design for new system extensions shall conform to these requirements to ensure system wide uniformity.

1.05 EXISTING SYSTEM CHARACTERISTICS

- A. The DC MPR shall be designed to operate in the BART system having the following characteristics:
 1. Peak fault current – 100,000 amperes, maximum (dc feeder fault for 10 MW rated traction power substations).
 2. Peak system operating current – For mainline dc circuit breakers rated at 4,000 amperes and above, current peaks of up to 11,000 amperes for up to 50-second duration.
 3. Rail Impedances:
 - a. Standard Contact Rail: 0.00387 ohms/1000 feet
 - b. Low Resistance Contact Rail: 0.00225 ohms/1000 feet
 - c. Running Rail (one track; two rails): 0.00485 ohms/1000 feet

PART 2 – PRODUCTS

2.01 GENERAL REQUIREMENTS

- A. DC MPR materials and equipment shall be designed to ensure satisfactory operation and operational life in the environmental conditions where the equipment will be installed, and shall be designed so that it is readily accessible for operation and maintenance.
- B. DC MPR equipment shall include operational modules located in the following dc switchgear compartments:

1. A main relay located in the associated dc feeder breaker control compartment
 2. An isolated high voltage signal measurement transducer located in the associated 1000V dc feeder bus compartment.
 3. Operator interface located on the exterior door of the associated dc feeder breaker control compartment.
- C. DC MPR equipment shall include all hardware, software, and ancillary circuits connecting between the various equipment modules so as to implement the protection, indication, load measuring and automatic reclosing functions specified herein
- D. Environmental requirements:
1. Temperature: Per IEEE 37.90-5.1.1
 2. Humidity: Per IEEE 37.90-5.1.2
 3. Dust: Equipment shall be capable of operating in an extremely dusty environment; and shall at a minimum meet the requirements of NEMA 12 type installation. All solid state and electro-mechanical equipment, relays, microprocessors, and ancillary equipment shall be rated for continuous operation in this environment.
 4. Equipment shall function as intended when subjected to all electromagnetic interference present in the vicinity of 1 kV dc power circuits and traction power equipment.

2.02 DC FEEDER BREAKER AUTOMATIC RECLOSING

- A. The load measuring and automatic reclosing circuits shall provide bi-directional reclosing logic, i.e. shall have the ability to load measure and automatically reclose the dc feeder breaker when either side of the dc feeder breaker circuit is energized and the other side is energized or de-energized. The MPR shall not allow reclosing if the dc buses on both sides of the circuit breaker are de-energized.
- B. The equipment Supplier shall theoretically and empirically demonstrate that the automatic reclosing scheme provides sufficient noise immunity to achieve the required voltage measurement sensitivity during peak period system operation.
- C. Definitions
1. 'Soft' Lockout: Normal system lockout caused by failure of a DC MPR to close its circuit breaker. Issuing a 'trip' signal to the relay or using a manual reset button shall clear a soft lockout condition.
 2. 'Hard' Lockout: A hard lockout condition caused by issuing too many close commands to a DC MPR within a programmable time period.

D. Automatic Reclosing System Parameters – The DC MPR shall at a minimum provide the following adjustable automatic reclosing system parameters, and shall use the given acronyms:

1. Bus Voltage High Threshold, **Vhi**: 500 to 1000VDC
2. Bus Voltage Low Threshold, **Vlo**: 0 to 500VDC
3. Minimum Line Resistance to Allow Reclosing, **Rlim**: 0.1 to 0.4 Ω
(**Rlim** is set = 0.2 Ω in the BART system)
4. Load Measurement Pulse Duration, **Pls**: 0.5 to 9.9 sec.
5. Delay between successive load measuring pulses, **Del**: 1 to 99 sec.
6. Load Measurement Delay (Lead, Neutral, Follow), **LNF**: -1=lead, 0=neutral, +1=follow. (Selectable delay to allow sequencing of load measurements for multiple dc feeder breakers connected to the same contact rail section, avoiding spurious MPR measurements caused by load measuring of adjacent dc feeder breaker MPR relays.)
7. Lead, Neutral, Follow Time Delay, **LNFDel**: 0 to 10 sec
8. Delay before starting first load measurement cycle, **Cdel**: 2 to 9 sec.
9. Successful Close Timer, **SucTm**: 0.5 to 3 sec.
(Time breaker shall remain closed to consider reclosing successful)
10. Load Measurement Attempts, **LMTry**: 1 to 4
(Number of times load measuring is attempted during one load measuring cycle)
11. Close Attempts, **CloseTry**: 1 to 4
(Number of times the circuit breaker is allowed to close and trip again during the Successful Close Time interval before system initiates a 'soft' lockout. Sending the dc feeder breaker a trip command shall clear a soft lockout.)
12. Soft Lockout Counter, **SoftLocksNum**: 1 to 5
(Number of times a soft lockout can be cleared during the hard lockout timer period that will initiate the hard lockout state)
13. Hard Lock Out Timer, **LockOutTime**: 1 to 99 min.
(Time during which a set number soft lockouts, counted by the Lockout Counter, initiates the hard lockout state.)

E. Automatic Reclosing System Functional Logic – DC MPR Automatic Reclosing System logic shall be in accordance with the Automatic Reclosing Routine Logic Diagram as shown in Figure 1 herein, and according to the following requirements:

1. Upon receipt of a 'Close' command, check status of the Hard Lockout Timer. If Hard Lockout Timer = 0, then start Hard Lockout Timer. If Hard Lockout Timer \neq 0, then increment the Lockout Counter. If the Lockout Counter < **SoftLocksNum** then after

the **Cdel** and **LNF** time delays begin auto-reclose cycle. If Lockout Counter = **SoftLockNum**, then go to the Hard Lockout state and give Hard Lockout indication.

2. On initiation of the auto-reclose cycle, measure the contact rail voltage. If contact rail voltage > **Vhi**, then close the dc feeder breaker and reset the appropriate counters and timers. If contact rail voltage is > **Vlo** then commence load measuring, and indicate 'Load Measuring/Reclosing'. If **Vlo** < Contact Rail Voltage < **Vhi** then indicate lockout, go to Lockout state, and reset the appropriate counters and timers.
3. Set Load Measuring Attempt Counter = 1 and measure contact rail voltage with the load-measuring resistor across the open dc feeder breaker. If the contact rail voltage measurement indicates a load resistance ≥ 0.2 ohms between the contact rail and negative return rail, then close the dc feeder breaker and reset the appropriate counters and timers. If this is not the case, then increment the Load Measuring Attempt Counter and try to reclose again.
4. If reclosing is unsuccessful after **LmTry** load measuring attempts, then go to the Lockout state, indicate Lockout, and reset the appropriate counters and timers.
5. If there is a number > **CloseTry** of successful reclosures and subsequent trips during the **SucTm** time setting, then indicate Lockout and go to Lockout state. Reset the appropriate counters and timers.
6. To clear a regular (soft) lockout, issue the dc feeder breaker DC MPR a 'trip' command. The DC MPR shall then accept and act on a subsequent 'close' command.

F. Auto-reclosing Logic Negative Rail Potential Rise Compensation: When evaluating contact rail voltage, the DC MPR shall measure the voltage between the dc positive contact rail and the dc negative return rail as shown by the following:

'MEASUREMENT' = ('CONTACT RAIL VOLTAGE' – 'NEGATIVE RAIL VOLTAGE')

This measurement shall be > the **Vhi** Contact Rail Energized Detection Threshold in order to reclose the dc feeder breaker.

BART DC MPR STANDARD

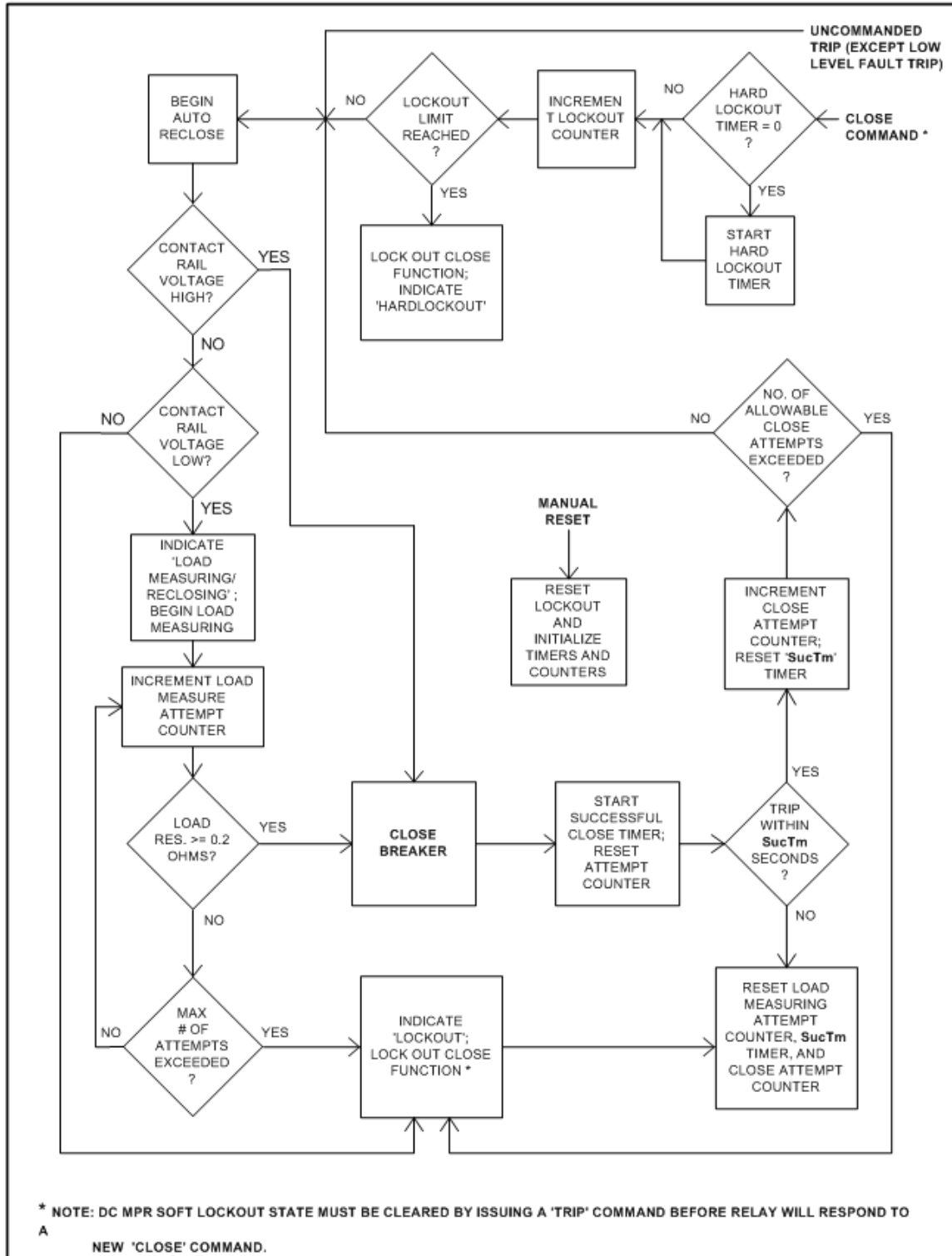


FIGURE 1 - AUTOMATIC CLOSING ROUTINE LOGIC DIAGRAM

2.03 SHORT CIRCUIT PROTECTION

- A. General: DC MPR protection functions shall, as a minimum, be as specified herein.
- B. Instantaneous Overcurrent Trip
 - 1. Trip Threshold, **I_{inst}**: 0.3 to 9 PU
 - 2. Trip Delay, **InstDel**: 0 to 250 millsec.
- C. Low Level Fault Trip
 - 1. Trip Threshold, **I_{LLF}**: 0.05 to 5 PU
 - 2. Trip Delay, **LLFDel**: 0.5 to 99 min.
- D. Timed Overcurrent Trip
 - 1. Trip Threshold, **I_{tmd}**: 0.2 to 2.5 PU
 - 2. Time Delay, **TmdDel**: 0.1 to 150 sec.
 - 3. Provide timed overcurrent trip function with inverse time characteristic that can be graphed with the set current, **I_{tmd}**, as the y-axis, and the time delay, **TmdDel**, as the x-axis. Tripping shall be initiated when the load current exceeds the set current during the period of time **t** such that (**t / TmdDel**) and (**I_{load} / I_{tmd}**) correspond to a point on the curve.
- E. Rate of Rise (ROR) Trip
 - 1. Current trip limit, **di/dt**: 1 to 50 PU/sec
 - 2. Current rise limit, **ΔI**: 0.1 to 2 PU
 - 3. Delay time, **Delay**: 40 to 400 millsec.
 - 4. Rate of rise trip shall be initiated if all of the following conditions are met:
 - a. Current di/dt exceeds the trip limit, **di/dt**
 - b. **di/dt** stays above the trip limit during the delay time, **Delay**
 - c. During the delay time current exceeds the current rise limit, **ΔI**

2.04 CONTACT RAIL POTENTIAL INDICATION

- A. Provide contact rail potential indication function with the following user-adjustable parameters:
 - 1. Pick-up voltage threshold, **Thr**: 0 to 1000V

2. Hysteresis, **Hst**: 0 to 300V
When the contact rail indication pickup voltage indicates an undervoltage condition, then **Thr** + **Hst** is the value at which the relay 'drops out' and the undervoltage indication becomes inactive. This prevents relay 'chattering'.
 3. Contact Rail Potential Undervoltage Pickup Delay: 0 to 3 sec.
- B. The Contact Rail Potential function shall be fail-safe such that if the device fails it shall indicate that the contact rail is energized.

2.05 RELAY DATA LOGGING

- A. General: Provide the following minimum data logging capabilities as specified herein.
- B. Alarm Memory: At a minimum, retain records of last 200 trips and/or alarms with date/time stamps. All trip events, failures to reclose, and system malfunctions shall be included among the alarms.
- C. Current and Voltage Measurements: Retain in non-volatile memory oscillogram type records of voltage and current traces for at least the last eight trip events. Each of the eight records shall consist of two sets of traces as follows:
1. One set shall store samples for the period of time from approximately 220 ms before the trip to 40 ms after the trip, with a 65 μ s sampling interval.
 2. The second set shall store samples for the period of time from approximately 230 sec. before and 30 sec after the trip, with a 65 ms sampling interval.

2.06 REMOTE COMMUNICATION

- A. Provide an RS-232 communications port enabling at a minimum the following remote user capabilities.
- B. View and configure all DC MPR functions and parameters
- C. Reset and trip the relay
- D. View and retrieve all alarm log and stored data traces
- E. View system diagnostics and status indications
- F. Download DC MPR operating software

2.07 OTHER RELAY REQUIREMENTS

- A. Control power: Provide dual and switchable power supply from 48V DC primary power and 120V AC back-up power sources.
- B. Memory: Program, alarm log, and recoded data traces shall be retained in non-volatile memory

- C. Noise rejection: Shall meet requirements of IEEE C37.90.1, 1989 – Surge Withstand Capability (SWC) Tests
- D. Local Operator Interface
 - 1. Minimum 4 x 20 alphanumeric backlit LCD display.
 - 2. Numeric or arrow keypad featuring pull-down menu allowing user to:
 - a. View relay settings
 - b. View alarm log
 - c. Change user-adjustable relay settings and parameters
 - d. View system diagnostics
- E. Data Inputs: Provide as a minimum the following input points rated for operation between 32 and 125V dc:
 - 1. Close command (coming from local or remote)
 - 2. Trip command (coming from local or remote)
 - 3. Trip-Reclose command (coming from transfer trip system)
 - 4. Breaker auxiliary contact
 - 5. Breaker position contact
 - 6. General purpose programmable input
- F. Trip Output: Provide SCR with optically isolated triggering circuit, rated 40A for 0.5 sec, 1A continuous, 300V dc maximum voltage.
- G. Relay Outputs: Provide as a minimum the following interfacing output contacts, rated 5 A at 30V dc resistive switching, 150V dc maximum contact voltage:
 - 1. Breaker close
 - 2. Load measurement contactor (Device 173) control
 - 3. System trouble/loss of control power
 - 4. Transfer trip initiate contact, forward direction
 - 5. Transfer trip initiate contact, reverse direction
 - 6. Transfer trip directional contact, forward direction

7. Transfer trip directional contact, reverse direction
8. Trip on overcurrent condition
9. Contact rail potential undervoltage
10. Instantaneous overcurrent trip
11. Timed overcurrent trip

H. Local LED Indications

1. Instantaneous overcurrent trip
2. Timed overcurrent trip
3. ROR trip
4. Lockout
5. Hard Lockout
6. DC MPR Healthy

I. Security

1. Provide, at a minimum, three levels of password-protected security:
 - a. Read only – Allows viewing of all relay parameters and stored data.
 - b. Basic programming – Allows programming of relay operating parameters.
 - c. Expert – Allows viewing and programming of internal relay software.
2. A physical lock/key type security system is not acceptable.

J. Relay Self-Monitoring: DC MPR shall initiate self-test on power-up, and shall continuously monitor internal operational integrity. Relay shall indicate any system trouble locally by an LED, and shall include an alarm contact to allow reporting of system trouble or loss of control power through SCADA. Provide capability to access internal system diagnostics both through the operator keypad or and through a PC via the RS-232 connection.

K. System Clock: Provide super-capacitor type power source for system clock that can power clock for at least 30 days after removal of control power.

2.08 HIGH VOLTAGE INPUT SIGNAL COLLECTION EQUIPMENT

A. Obtain required voltage and current indications using shunts with transducers mounted in the switchgear 1000V-dc feeder compartment(s). Provide HV signal collection equipment

and connections to the control compartment that are sufficiently rugged to withstand dust, dirt, and any expected thermal, mechanical and electrical stresses associated with the 1000V dc circuits. The signal collection equipment shall provide isolation from the 1000V-dc buswork as indicated below.

- B. Provide transducer with following minimum characteristics:
 - 1. Isolation:
 - a. Continuous: 4 kV
 - b. Peak: 8 kV test
 - 2. Accuracy: $\pm 2\%$ Full Scale
 - 3. Current Range: 0 – 25 kA
 - 4. Mounting: Shall be of adequate strength to withstand all thermal and mechanical stresses associated with the maximum short-circuit currents equal to the interrupting rating of the circuit breakers indicated above.
- C. Connection between signal collection equipment and DC MPR located in the control compartment shall use a 2-way fiber optic serial connection – forward link shall transmit data and reverse link shall monitor transducer function. Any detected transducer or fiber optic cable malfunction shall initiate a DC MPR trouble indication. Fiber optic cable shall be sufficiently rugged to withstand all expected thermal, mechanical, and electrical stresses.
- D. Shunts shall be used to obtain required current and voltage. Hall Effect type sensors are not acceptable.
- E. Provide any required bleeder resistors between dc positive and negative buses and voltage transducer to ensure adequate filtering of random transient voltages inherent in traction power rectifiers and 1000V dc switchgear.

PART 3 – EXECUTION

Not Used

END OF SECTION 34 21 11